Summary

In recent years researchers have realized that natural environments are far more complex than, for example, a 3.5% sodium chloride solution often used to simulate seawater, and that trace elements present in real environments can have considerable effects on the corrosion performance of metals. Investigations in complex environments can lead to a large number of experiments. Koch et al. have described a method to handle the effects of a large number of variables on the corrosion behavior of metals and to enable better simulation of chemical species within these complex environments. With a suitable experimental design a mathematical expression can be developed that describes the effect of several independent variables on corrosion behavior. Several examples are given in this paper to demonstrate the technique. Two of these examples are covered in greater detail by other authors. Mansfeld and Jeanjaquet used synthetic environments to study the corrosion of materials used in flue-gas desulfurization plants. Their study on Ferralium 255, Hastelloy G3, stainless steel (Type 317L), Monit and titanium (Grade 2) highlighted the importance of the composition of the synthetic environment used for these tests. Relatively minor variations in the chemistry of the synthetic test solutions had a marked effect on the corrosion performance of the alloys tested. For a given solution composition, high corrosion rates could occur for some alloys while others remained virtually unattacked. Hindin and Agrawal used synthetic environments to study the corrosion performance of candidate materials for use in residential high-efficiency condensing furnaces.

Haynes and Baboian described experience with synthetic environments for testing automobile body trim. In addition to road salts, atmospheric pollutants, such as SO_2 and NO_x have an important bearing on automobile corrosion. These pollutants can react on the metal surface to form corrosive acids. The industry has not been able to simulate this complex environment accurately in the laboratory and relies heavily on proving ground tests.

Fiaud supports the above findings, and in his paper comments that despite extensive work over a period of 70 years in the field of atmospheric corrosion many questions remain and no satisfactory method for predicting the performance of materials in the atmosphere exists. Fiaud lists the requirements of indoor and outdoor environments for corrosion testing and highlights the importance of SO_2, NO_x, and Cl_2 in the atmospheric corrosion of metals.

Murphy and Pape described the role of synthetic media in the study of metal food containers. Even very low corrosion rates can be harmful to the contents of the containers, for example, dissolution of tin or iron from tinplate or of aluminum from the body or end stock. Slight stains on the metal surface might not be harmful, but are undesirable. Synthetic environments have to be carefully formulated to simulate complex natural food materials. They concluded that the use of synthetic media is useful for studying basic principles like the complexing action of fruit acids, but there is always a need to support tests using synthetic environments with studies on actual products to be packed.

Kuhn et al. reviewed the use of synthetic environments for testing metallic biomaterials. They suggest that the best experimental techniques have not always been applied to measurements of corrosion in body fluids, and that the correlation between in-vivo and in-vitro corrosion rates is far from satisfactory in many cases.

Stott et al. described the evaluation of materials for resistance to sulfate reducing bacteria (SRB). Traditionally, the testing of materials against anaerobic corrosion caused by SRB has been carried out in small-scale "batch cultures" using filled and stoppered vessels or small cells contained in "anaerobic jars." These authors point out that such tests give much lower corrosion rates than those frequently experienced in the field. The reasons for this are outlined in the
paper. Some workers have used semi-continuous cultures to overcome some of the shortcomings of the "batch culture" test. The authors have outlined the features required for a satisfactory test environment for measurement of the resistance of materials to SRB. They describe an experimental rig design that produced an environment containing SRB, which generated without artificial acceleration high metallic corrosion rates comparable to those in naturally occurring corrosion processes.

The microbial theme was continued by Hill et al. who described the use of synthetic environments to simulate the microbial environment in the metal-working fluid in a machine tool coolant system.

These authors stressed the difficulty in simulating metal-working fluid spoilage in the laboratory using simple shake flasks. For organisms to develop and an environment to become established which relates closely to those in machine tool coolant systems, the test procedure must include an aeration phase, a piped phase, an adequately sized sump, and appropriate metal swarf. A synthetic environment has been used by these authors to rank biocides for use in machine tool coolant systems.

Kolts et al. investigated standard tests and environments for ranking the pitting and general corrosion resistance of stainless steels and nickel-base alloys. They found excellent correlation between field tests and pitting resistance determined from measurements of critical pitting temperatures in chloride solutions containing ferric ions. Correlations for general corrosion were found to be poor.

Parkins pointed out that evidence for the cracking domain for ferritic steels and \(\alpha\)-brasses suggests that SCC in a range of environments occurs at potentials and pH values where the lower oxide of the relevant metal form. This suggests that laboratory tests for SCC should involve more than a single standardized environment and that variation from test to test of potential and pH, guided by the potential pH diagram may provide a more reliable guide to SCC propensity than that obtained from tests in a single solution. Various alloy systems were considered in the paper.

Johns described a method for assessing the sensitization to intergranular corrosion of austenitic stainless steel based on potentiokinetic polarization in a perchloric acid/sodium chloride solution. The data obtained correlated well with penetration rate values recorded in the boiling nitric acid test, ASTM C262-75 Practice C.

Mattsson et al. have described an ammonia test for the evaluation of the stress corrosion resistance of copper alloy products. The test procedure involves a 24-h exposure of the test material at room temperature to an ammoniacal atmosphere in equilibrium with an ammonium chloride solution. The vapor pressure of ammonia in equilibrium with the test solution depends on the pH value. Hence the severity of the test can be regulated by changing the pH value. With a pH of 9.5 the test was shown to correlate well with four-year field trials. The test has been proposed for (ISO) standardization.

Goodman et al. have described a test cell that provides the conditions that lead to Type I pitting of copper in potable waters.

A detailed explanation of the mechanism of pit initiation in the test cell is given, and a synthetic pitting solution, which may be used to check the quality of copper tubes, was described.

Several contributors discussed the use of natural and synthetic seawater for corrosion testing. Castle et al. described their experience in holding natural seawater in the laboratory. They made a detailed study of the microorganisms that developed in the holding tanks over a period of 78 days. They also separated the organic component from seawater by ultrafiltration and added it to synthetic mixes. Using these techniques they described the influence of organic natural products on the corrosion of Kunife 10.

Thomas and Cheung draw attention to the inaccuracies that occur in measurement of corrosion and erosion-corrosion of copper-nickel alloys in synthetic seawater contained in a recirculating loop. Buildup of small quantities of heavy metals in the loop environment leads to spurious results. A method of overcoming this problem was described.
Money and Kain reviewed relative merits of synthetic and natural marine environments (atmospheric and immersed) for corrosion testing. They drew attention to the difference between the use of synthetic environments to simulate natural environments and accelerated test methods that are used to reduce the timescale of the tests. Synthetic environments established for one material must be applied to other materials with great care.

Dexter reviewed the factors contributing to the variability of aluminum corrosion data in saline waters. He has evaluated the requirements of synthetic seawater for studies on the corrosion of aluminum which can reproduce closely the short-term behavior of aluminum alloys, and described an enhanced sodium chloride solution, more simple and more stable than either natural or standard synthetic seawater, which can closely reproduce the short-term behavior of aluminum alloys in seawater.

Kohley and Heitz described a suitable test medium and test method for examining the erosion-corrosion of 13% chromium steel in formation waters containing particulate matter (sand particles). Continuing the theme of hydrocarbon production, McIntyre described suitable methods of assessing the pitting propensity of seawater environments and condensates containing quaternary amines as corrosion inhibitors at 65°C in a CO₂ atmosphere.

Two papers addressed the problem of simulation of synthetic environments for steel in concrete. Sykes and Balkwill compared results from tests on specimens embedded in ordinary portland cement mortar, calcium hydroxide solutions, and a gel made from alkaline solution and chloride ions. They demonstrated that the pitting behavior of steel in gels was markedly different from that in alkaline solution themselves, and that portland cement mortar was less aggressive than the gel.

Dawson and Langford presented data on steel embedded in portland cement mortar and extracted pore solutions. They concluded that although measurements in pore solutions are useful, such an approach has limited application to longer term concrete durability studies.

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